TITLE OF THE INVENTION

MICROMIRROR DRIVER AND METHOD OF CONTROLLING MICROMIRROR DRIVER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Application Nos. 2001-10916 and 2001-10917, both filed March 2, 2001, in the Korean Patent Office, the disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a micromirror driver, and more particularly, to a micromirror driver which controls a resonant frequency and an amplitude of a micromirror as the micromirror rotates due to electrostatic forces, and increases a rotation angle of the micromirror using a lower voltage, and to a method of controlling the micromirror driver.

2. Description of the Related Art

[0003] In general, micromirror drivers are operated by electrostatic forces and switch a path, along which light beams are reflected, using a rotation angle of a micromirror.

[0004] Referring to FIG. 1, a conventional micromirror driver comprises a frame 5, a trench 10 formed in the frame 5, a micromirror 20 received in the trench 10 and having a base electrode 15, a torsion spring 25 which supports the micromirror 20 in rotation, and an electrode 30 which interacts with the base electrode 15 to rotate the micromirror 20.

[0005] The micromirror 20 rotates about the torsion spring 25 due to electrostatic forces generated between the base electrode 15 and the electrode 30, as shown in FIG. 2. If the micromirror sufficiently rotates with a predetermined rotation angle, the micromirror 20 is restored to a horizontal state due to elastic restoring forces of the torsion spring 25. The micromirror 20 repeatedly rotates in the above-described manner. It is possible to allow a rotating body, such as the micromirror 20, to rotate with a greater rotation angle with a use of less voltage, taking advantage of resonance characteristics of an oscillating body. In other words, it is possible to effectively operate an oscillating body with less driving forces if the

oscillating body is operated with a frequency, which is the same as a resonant frequency of the oscillating body.

[0006] A conventional method of adjusting the resonant frequency of a micromirror increases or decreases a mass of the micromirror and a spring constant of a torsion spring. However, such a mass of the micromirror and the spring constant of a torsion spring are set in accordance with manufacturing conditions and may vary according to an environment, in which the micromirror is manufactured or is driven. Accordingly, it is difficult to obtain a precise resonant frequency of the micromirror due to variations in the manufacture of the micromirror. Thus, various efforts have been made to control the resonant frequency of a micromirror after manufacturing the micromirror.

[0007] The resonant frequency f of an oscillating body can be expressed by Equation (1).

$$f = \frac{1}{2\pi}\sqrt{\frac{K_t}{I}} \quad \cdots(1)$$

[0008] In Equation (1), K_t represents a spring constant, and I represents an inertia moment.

[0009] The equation of motion concerning the micromirror 20 rotating with a predetermined rotation angle (θ) is shown below as Equation (2).

$$\begin{aligned} I\ddot{\theta} + C_t\dot{\theta} + K_t\theta &= \tau(\theta,V) \\ &= \frac{1}{2}\frac{d}{d\theta}(CV^2) \quad \cdots(2) \end{aligned}$$

[0010] In Equation (2), I represents an inertia moment, C_t represents capacitance between the base electrode 15 of the micromirror 20 and the electrode 30, K_t represents the spring constant of the torsion spring 25, and τ represents a rotation moment (torque). Where V_0, α, and V represent an initial voltage of the electrode 30, an arbitrary coefficient, and a driving voltage of the electrode 30, respectively, and $V=(V_0+\alpha\theta)$, Equation (2) can be rearranged into Equation (3)

$$I\ddot{\theta} + C_t\dot{\theta} + K_t\theta = \frac{1}{2}\frac{dC}{d\theta}V^2 + \frac{1}{2}C(2V)\frac{dV}{d\theta}$$
$$= \frac{1}{2}\frac{dC}{d\theta}(V_0^2 + 2V_0\alpha\theta + \alpha^2\theta^2) + \frac{1}{2}C2(V_0 + \alpha\theta)\alpha \quad \cdots(3)$$

by substitution of $V=(V_0+\alpha\theta)$.

[0011] The capacitance C_t is linearly varied with respect to the rotation angle θ of the micromirror 20, as shown in FIG. 3. In other words, as the rotation angle θ of the micromirror 20 increases, the distance between the base electrode 15 and the electrode 30 increases, and thus the capacitance C_t linearly decreases. Accordingly, a variation of the capacitance C_t with respect to a variation of the rotation angle θ becomes a constant γ. The constant γ can be expressed as $\frac{dC}{d\theta} = \gamma$. Accordingly, $C=C_o+\gamma\theta$ where C_o represents a capacitance value when $\theta = 0$. Equation (3) can be rearranged into Equation (4) by substitutions of $\frac{dC}{d\theta} = \gamma$ and $C=C_o+\gamma\theta$.

$$I\ddot{\theta} + C_t\dot{\theta} + K_t\theta = \frac{1}{2}[(\gamma V_0 + 2\alpha C_0)V_0 + (4\gamma\alpha V_0 + 2\alpha^2 C_0)\theta + 3\gamma\alpha^2\theta^2] \quad \cdots(4)$$

[0012] In the right side of Equation (4), $(\gamma V_o+2\alpha C_o)$ affects the rotation amplitude of the micromirror 20, $(4\gamma\alpha V_o+2\alpha^2 C_o)$ affects the resonant frequency f of the micromirror 20, and $3\gamma\alpha^2$ affects both the amplitude and the resonant frequency of the micromirror 20. Here, if the resonant frequency f of the micromirror 20 is controlled by adjusting α, the voltage V of the driving voltage of the electrode 30 is varied because $V= (V_0+\alpha\theta)$. If the initial voltage V_0 of the electrode 30 is varied, α is also varied. Thus, it is impossible to simultaneously control the frequency f and the amplitude of the micromirror 20. In other words, elements required to control the frequency f and the amplitude of the micromirror 20 are dependent on each other, and thus if one of the elements is controlled, the other element is affected by the controlled element and cannot be controlled simultaneously or independently.

SUMMARY OF THE INVENTION

[0013] To solve the above-described problems, it is an object of the present invention to provide a micromirror driver, in which a frequency controlling electrode and an amplitude controlling electrode operate independently and thus a resonant frequency and an amplitude of a micromirror are independently and simultaneously controllable, allowing the micromirror to rotate with a larger rotation angle by decreasing a spring constant of a rotation axis of the micromirror. Another object of the present invention is to provide a method of controlling a micromirror driver.

[0014] Additional objects and advantages of the invention will be set forth in part in the description which follows, and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0015] Accordingly, to achieve the above and other objects of the invention, according to one aspect of the present invention, there is provided a micromirror driver. The micromirror driver comprises a micromirror having at least one groove, an elastic body which supports the micromirror in rotation, and at least one electrode which receives a voltage to generate electrostatic forces to rotate the micromirror through interaction of the electrostatic forces with the micromirror. The amplitude and frequency of the micromirror are controlled by varying one of a magnitude and a waveform of the voltage of the at least one electrode.

[0016] Each groove is formed in a respective peripheral area of the micromirror and is arranged near a rotation axis of the micromirror.

[0017] Preferably, a first electrode controls the frequency of the micromirror during rotation of the micromirror, a second electrode controls the amplitude of the micromirror during the rotation of the micromirror, and the second electrode operates independently of the first electrode.

[0018] A voltage V of the at least one electrode satisfies the equation, $V^2=V_0+\alpha\theta$, where V_0 represents an initial voltage of the at least one electrode, α represents an arbitrary coefficient, and θ represents a rotation angle of the micromirror. A voltage V_1 of the first electrode satisfies the equation, $V_1^2=V_0$,and a voltage V_2 of the second electrode satisfies the equation, $V_2^2=V_0$.

[0019] A base electrode is formed on the micromirror and the base electrode and the first and second electrodes are formed in a comb shape and the combs of the first and second electrodes and the comb of the base electrode are arranged gear-like so that an effective area of opposing surfaces of the electrodes is maximized.

[0020] Preferably, a plurality of grooves are formed in the micromirror and arranged symmetrically with respect to the rotation axis of the micromirror.

[0021] In order to achieve the above and other objects of the present invention, according to another aspect of the present invention, there is provided a micromirror driver. The micromirror driver comprises a micromirror having at least one groove and a base electrode formed at the groove, an elastic body which supports the micromirror in rotation, and at least two electrodes which drive the micromirror in rotation by generating electrostatic forces through interaction of the at least two electrodes with the base electrode and, the at least two electrodes operating independently of each other.

[0022] One of the at least two electrodes is used to control the frequency of the micromirror by varying a waveform of a voltage applied to the one electrode.

[0023] The other of the at least two electrodes is used to control the amplitude of the micromirror by varying the magnitude of the voltage applied to the other of the at least two electrodes.

[0024] In order to achieve the above and other objects of the present invention, according to another aspect of the present invention, there is provided a method of controlling a micromirror driver, which comprises a micromirror, an elastic body supporting the micromirror in rotation, and at least one electrode. The method comprises: generating electrostatic forces between the micromirror and the at least one electrode; a voltage V of the at least one electrode to satisfy an equation, $V^2=V_0+\alpha\theta$ where V_0 represents an initial voltage of the at least one electrode, α represents an arbitrary coefficient, and θ represents a rotation angle of the micromirror; and controlling a frequency and/or an amplitude of the micromirror by varying the initial voltage V_0 of the at least one electrode and the arbitrary coefficient α.

[0025] Preferably, a second electrode controls a resonant frequency f of the micromirror by varying the arbitrary coefficient α in an equation, $V^2=\alpha\theta$, and the resonant frequency f of the micromirror is expressed by the equation,

$$f = \frac{1}{2\pi}\sqrt{\frac{K_t - \gamma_2\alpha}{I}}$$

wherein K_t represents the spring constant of the elastic body, I represents an inertia moment of the micromirror, and γ_2 represents a variation of capacitance with respect to a variation of the rotation angle θ of the micromirror.

[0026] The second electrode controls the resonant frequency f of the micromirror by varying the arbitrary coefficient α in the equation, $V^2=\alpha\theta$, and in a case where a voltage with a phase difference of $\pi/2$ is applied to the first and second electrodes, the resonant frequency f of the micromirror can be expressed by the equation,

$$f = \frac{1}{2\pi}\sqrt{\frac{K_t + \gamma_2\alpha}{I}}$$

wherein K_t represents the spring constant of the elastic body, I represents the inertia moment of the micromirror, and γ_2 represents a variation of capacitance with respect to a variation of the rotation angle θ of the micromirror.

[0027] In order to achieve the above and other objects, according to another aspect of the present invention, there is provided a method of controlling a micromirror driver, which comprises a micromirror, an elastic body supporting the micromirror in rotation, and at least one electrode which rotates the micromirror by generating electrostatic forces through interaction with the micromirror. The method includes the step of comprising controlling the resonant frequency of the micromirror by varying the waveform of the driving voltage of the at least one electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The above objects and advantages of the present invention will become more apparent by describing in detail an embodiment thereof with reference to the attached drawings in which:

FIG. 1 is a schematic plan view of a conventional micromirror driver;

FIG. 2 is a diagram illustrating rotation of a conventional micromirror;

FIG. 3 is a graph showing a variation of capacitance with respect to a rotation angle of a conventional micromirror;

FIG. 4A is a plan view of a micromirror driver according to an embodiment the present invention;

FIG. 4B is an enlarged view of a portion of FIG. 4A, showing an engagement of a first portion of a base electrode and a driver electrode;

FIG. 4C is an enlarged view of a portion of FIG. 4A, showing an engagement of a second portion of the base electrode and another driver electrode;

FIG. 5 is a graph showing a relationship between a driving voltage and motion of a micromirror according to an embodiment of the present invention; and

FIG. 6 is a graph showing a variation of the driving voltage of the micromirror with respect to a rotation angle of the micromirror.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Reference will now be made in detail to the present embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0030] Referring to FIGS. 4A, 4B and 4C, a micromirror driver according to the present invention comprises a frame 100, a micromirror 110, a trench 108 having sufficient space in which to rotate the micromirror 110, an elastic body 105 which elastically supports the micromirror in rotation, and at least one electrode to drive the micromirror 110.

[0031] The micromirror 110 comprises a reflector 110a, by which light beams incident on the micromirror 110 are reflected, and at least one groove 110b formed in a peripheral area of the reflector 110a.

[0032] A first electrode 115, controls a rotation amplitude of the micromirror 110 according to a magnitude of a first voltage applied to the first electrode 115, and second electrodes 120, 121, 122, and 123, control a resonant frequency f of the micromirror 110 by controlling a waveform of a second voltage applied to at least one of the second electrodes 120, 121, 122 and 123, the second electrodes operating independently of the first electrode 115. The first electrode 115 is located at a side or both sides of the trench 108 in a direction parallel with the elastic body 105. Preferably, the second electrodes 120, 121, 122, and 123 are each located to be inserted into a respective groove 110b.

[0033] A base electrode 113, which interacts with the first electrode 115 and the second electrodes 120, 121, 122, and 123 to generate electrostatic forces, is located to face the first electrode 115 and the second electrodes 120, 121, 122, and 123. In particular, since the base electrode 113 is formed at sidewalls of the groove 110b of the micromirror 110, the effective area where the driving force of the micromirror is primarily obtained is maximized. That is, a larger area for interaction of the electrodes is obtained, which serves to enhance the driving force of the micromirror, where the groove 110b is formed around the micromirror 110 as compared with a conventional micromirror formed in a plate shape without a groove. In order to maximize the area of the opposing surface of the base electrode 113 and the first and second electrodes 115, and 120 through 123, the first electrode 115, the second electrodes 120 through 123, and the base electrode 113 are formed in a comb shape. The first electrode 115 comprises a plurality of projections 115a as shown in FIG. 4B and the second electrodes 120 through 123 each comprise a plurality of projections of which the projections 122a shown in FIG. 4C are exemplary. The base electrode 113 comprises a plurality of projections 113a which are arranged to be in gear with the projections 115a of the first electrode 115 or the projections of each of the second electrodes 120 through 123. The reflector 110a may be formed to have a minimum surface area as long as the reflector 110a does not lose a function of reflection of light beams. Preferably, the grooves 110b are formed to be symmetrical with respect to a rotation axis C of the micromirror 110.

[0034] Next, a method of controlling a micromirror driver having structure as described with reference to FIG. 4 will be described below.

[0035] The micromirror 110 is rotated due to electrostatic forces generated by interaction between the base electrode 113 and the first and second electrodes 115, and 120 through 123. Here, a voltage V of the electrodes used to drive the micromirror 110 is expressed by a term for determining the magnitude of the voltage V and a term for determining a waveform of the voltage V. For example, the driving voltage V of the micromirror 110 is formed into $V^2=V_0+\alpha\theta$ where V_0 represents an initial voltage and α represents an arbitrary coefficient.

[0036] FIG. 5 is a graph showing time to apply a driving voltage V and variation of the waveform of the driving voltage V with respect to an arbitrary coefficient α according to the motion of the micromirror 110. Here, a critical angle θc represents the maximum angle, by which the micromirror 110 is rotated due to electrostatic forces. As shown in FIG. 5, the waveform of the voltage varies in accordance with α variations.

[0037] FIG. 6 is a graph showing variation of a driving voltage V^2 with respect to a rotation angle θ. As shown in FIG. 6, the driving voltage V^2 is proportional to the rotation angle θ of the micromirror 110, and accordingly, α depends on an initial voltage V_0 when the driving voltage V^2 reaches a predetermined level. In other words, if the initial value V_0 is varied when the driving voltage V^2 reaches a predetermined level, α also varies.

[0038] In a case where $V^2=V_0+\alpha\theta$ and only one electrode is used, Equation (2) can be rearranged into Equation (5) by substitution of V^2.

$$\begin{aligned} I\ddot{\theta}+ C_t\dot{\theta}+ K_t\theta &= \frac{1}{2}\frac{d}{d\theta}(CV^2) \qquad \cdots(5) \\ &= \frac{1}{2}\frac{dC}{d\theta}V^2 + \frac{1}{2}C\frac{dV^2}{d\theta} \\ &= \frac{1}{2}\frac{dC}{d\theta}(V_0 + \alpha\theta) + \frac{1}{2}C\alpha \end{aligned}$$

[0039] As described above, if $\frac{dC}{d\theta} = \gamma$, $C=C_0+\gamma\theta$. Accordingly, Equation (5) can be rearranged into Equation (6) by the substitution of $\frac{dC}{d\theta} = \gamma$ and $C=C_0+\gamma\theta$.

$$I\ddot{\theta}+ C_t\dot{\theta}+ [K_t - \gamma\alpha]\theta = \frac{1}{2}(\gamma V_0 + \alpha C_0) \qquad \cdots(6)$$

[0040] Here, $K_t - \gamma\alpha$ affects the frequency of the micromirror 110, and $\frac{1}{2}(\gamma V_0 + \alpha C_0)$ affects the amplitude of the micromirror 110. According to Equation (6), the frequency f is controllable, while varying the coefficient α and amplitude of the micromirror 110, and while varying the initial voltage V_0.

[0041] In a case where $V^2=V_0+\alpha\theta$, $V_1^2=V_0$, and $V_2^2=\alpha\theta$ (V_1 represents the voltage of the first electrode, and V_2 represents the voltage of the second electrodes), the driving voltage V of the micromirror 110 can be expressed by Equation (7).

$$
\begin{aligned}
V &= V_1^2 + V_2^2 \qquad \cdots(7)\\
V_1^2 &= V_0,\\
V_2^2 &= \alpha\theta
\end{aligned}
$$

[0042] Equation (8) can be obtained by substituting Equation (7) into Equation (2) and rearranging Equation (2) with respect to the rotation angle θ of the micromirror 110.

$$
\begin{aligned}
I\ddot{\theta} + C_t\dot{\theta} + K_t\theta &= \frac{1}{2}\frac{d}{d\theta}(CV^2) \qquad \cdots(8)\\
&= \frac{1}{2}\left(\frac{dC}{d\theta}\right)(V_1^2 + V_2^2) + \frac{1}{2}C\frac{d}{d\theta}(V_1^2 + V_2^2)\\
&= \frac{1}{2}\left(\frac{dC}{d\theta}\right)V_1^2 + \frac{1}{2}\left(\frac{dC}{d\theta}\right)V_2^2 + \frac{1}{2}C\left(\frac{dV_1^2}{d\theta}\right) + \frac{1}{2}C\left(\frac{dV_2^2}{d\theta}\right)
\end{aligned}
$$

[0043] In the right side of Equation (8), $(\frac{dC}{d\theta})$ of the first term concerns the first electrode 115 and thus will be marked with subscript 1. On the other hand, $(\frac{dC}{d\theta})$ of the second term concerns the second electrodes 120 through 123 and thus will be marked with subscript 2. As described above, C varies linearly with respect to θ, and thus the differentiation terms of capacitance with respect to θ, concerning the first and second electrodes 115, and 120 through 123, can be represented by γ_1 and γ_2, respectively. Accordingly, $(\frac{dC}{d\theta})_1 = \gamma_1$ and $(\frac{dC}{d\theta})_2 = \gamma_2$.

[0044] Equation (8) can be rearranged into Equation (9) by substitution of $V_1^2=V_0$ and $V_2^2=\alpha\theta$.

$$
I\ddot{\theta} + C_t\dot{\theta} + K_t\theta = \frac{1}{2}\gamma_1 V_0 + \frac{1}{2}\gamma_2\alpha\theta + \frac{1}{2}C_2\alpha \qquad \cdots(9)
$$

[0045] Equation (9) can be rearranged into Equation (10) by substitution of $C_2=C_{20}+\gamma_2\theta$ where C_{20} represents the value of C_2 when θ is 0.

$$I\ddot{\theta}+C_t\dot{\theta}+K_t\theta=\frac{1}{2}\gamma_1V_0+\frac{1}{2}\gamma_2\alpha\theta+\frac{1}{2}(C_{20}+\gamma_2\theta)\alpha \quad \cdots(10)$$
$$=\frac{1}{2}\gamma_1V_0+\gamma_2\alpha\theta+\frac{1}{2}C_{20}\alpha$$

[0046] Equation (10) can be rearranged with respect to the rotation angle θ of the micromirror 110 into Equation (11).

$$I\ddot{\theta}+C_t\dot{\theta}+(K_t-\gamma_2\alpha)\theta=\frac{1}{2}(\gamma_1V_0+\alpha C_{20}) \quad \cdots(11)$$

$(K_t-\gamma_2\alpha)$ in the left side of Equation (11), which is the coefficient of θ, affects the resonant frequency f of the micromirror 110, and $\frac{1}{2}(\gamma_1V_0+\alpha C_{20})$ in the right side of Equation (11) affects the amplitude of the micromirror 110. In other words, the resonant frequency f of the micromirror can be expressed by Equation (12) using Equations (1), (2), and (11).

$$f=\frac{1}{2\pi}\sqrt{\frac{K_t-\gamma_2\alpha}{I}} \quad \cdots(12)$$

[0047] According to Equation (12), the resonant frequency f of the micromirror 110 is controllable by varying an arbitrary coefficient α. The amplitude of the micromirror 110 can be controlled by $\frac{1}{2}(\gamma_1V_0+\alpha C_{20})$ of Equation (11). Where the resonant frequency f of the micromirror 110 is controlled by varying α, the amplitude of the micromirror 110 is also affected by the variation of α. However, the amplitude of the micromirror 110 is controllable by controlling V_0. Here, since V_0 is an independent variable, which is not affected by the variation of α, the amplitude of the micromirror 110 is controllable independently of the control of the resonant frequency f of the micromirror 110. Accordingly, the resonant frequency and amplitude of the micromirror 110 are satisfactorily controllable independently and simultaneously.

[0048] In another method of controlling a micromirror driver, the resonant frequency f of the micromirror 110 is controllable by applying a voltage with a predetermined phase difference to the first and second electrodes 115, and 120 through 123. For example, if voltages with a phase difference of $\pi/2$ are applied to the first and second electrodes 115, and 120 through 123, $\gamma_2\alpha$ has a negative value. Thus, the resonant frequency f of the micromirror 110 can be expressed by Equation (13).

$$f = \frac{1}{2\pi}\sqrt{\frac{K_t + \gamma_2\alpha}{I}} \quad \cdots(13)$$

[0049] Here, K_t represents the spring constant of the elastic body 105, I represents inertia moment, and γ_2 represents a variation of capacitance with respect to a variation of the rotation angle θ of the micromirror 110. According to Equation (13), the resonant frequency f of the micromirror 110 is controllable by controlling an arbitrary coefficient α, which determines the waveform of the voltage.

[0050] As described above, since the micromirror 110 in the micromirror driver according to the present invention includes the groove 110b to maximize an area prepared for electrodes to be installed, the mass of the micromirror 110 can be reduced to less than a mass of a conventional plate-shaped micromirror. As the mass of the micromirror 110 decreases, the inertia moment I of the micromirror 110 decreases. If the inertia moment I of the micromirror 110 decreases, and the resonant frequency f of the micromirror 110 is maintained at a predetermined level, the spring constant K_t of the elastic body 105 decreases according to Equation (12). However, the micromirror 110 is driven against restoring elastic forces of the elastic body 105 having a predetermined spring constant K_t. Thus, as the elastic body 105 has a lower spring constant K_t, less driving force is required to rotate the micromirror 110 with a predetermined rotation angle. In other words, as the spring constant K_t of the elastic body 105 becomes lower, a larger rotation angle of the micromirror 110 is obtained with less driving force. Accordingly, the micromirror driver according to the present invention uses the groove 110b as an area prepared for electrodes to be installed and reduces the spring constant K_t of the elastic body 105 with the use of the groove 110b.

[0051] As described above, the base electrode 113 and the first and second electrodes 115, and 120 through 123 are formed in a comb shape. Since the base electrode 113 is arranged to be in gear with the first or second electrodes 115, or 120 through 123, the area of the opposing surface of the base electrode 113 and the first or second electrodes 115, and 120 through 123 is maximized, and thus effective electrostatic forces generated by interaction between the base electrode 113 and the first and second electrodes 115, and 120 through 123 is maximized with the use of a predetermined voltage.

[0052] In the meantime, as the distance L1 (FIG. 3) between the rotation axis C of the micromirror 110 and the first or second electrodes 115, or 120 through 123 decreases, the critical angle θ_c of the micromirror 110 increases. If the critical angle θ_c of the micromirror 110 increases, the degree, to which electrostatic forces affect the micromirror 110 increases, and thus the range, in which the resonant frequency f of the micromirror 110 is controllable, increases even when the micromirror 110 rotates with a very large rotation angle. In the present invention, since the first and second electrodes 115, or 120 through 123 are arranged at the sidewalls of the groove, the distance L1 between the rotation axis of the micromirror 110 and the first or second electrodes 115, or 120 through 123 is minimized.

[0053] As described above, since the micromirror driver according to the present invention includes a electrode which controls the resonant frequency of a micromirror and a second electrode which controls the amplitude of the micromirror, which operates independently of the resonant frequency controlling electrode and is not affected by the resonant frequency controlling electrode, the resonant frequency and the amplitude of the micromirror are controllable simultaneously and independently of each other.

[0054] In addition, the micromirror driver according to the present invention obtains a large rotation angle of the micromirror by reducing the inertia moment of the micromirror and the spring constant of the elastic body, while maintaining the effective area of the micromirror.

[0055] Finally, since an area which engages the resonant frequency controlling electrode and an area which engages the amplitude controlling electrode are prepared in the micromirror of the micromirror driver according to the present invention, greater driving forces are obtained with the use of less voltage. In addition, since the distance between the rotation axis of the micromirror and the controlling electrodes is reduced and the area of the

opposing surface of electrodes interacting with each other is increased, the range, in which the resonant frequency of the micromirror is controllable, is expanded even where the micromirror rotates with a very large rotation angle.

[0056] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.